Importance Ranking of Survivability Issues in an Aging System

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Original Purpose

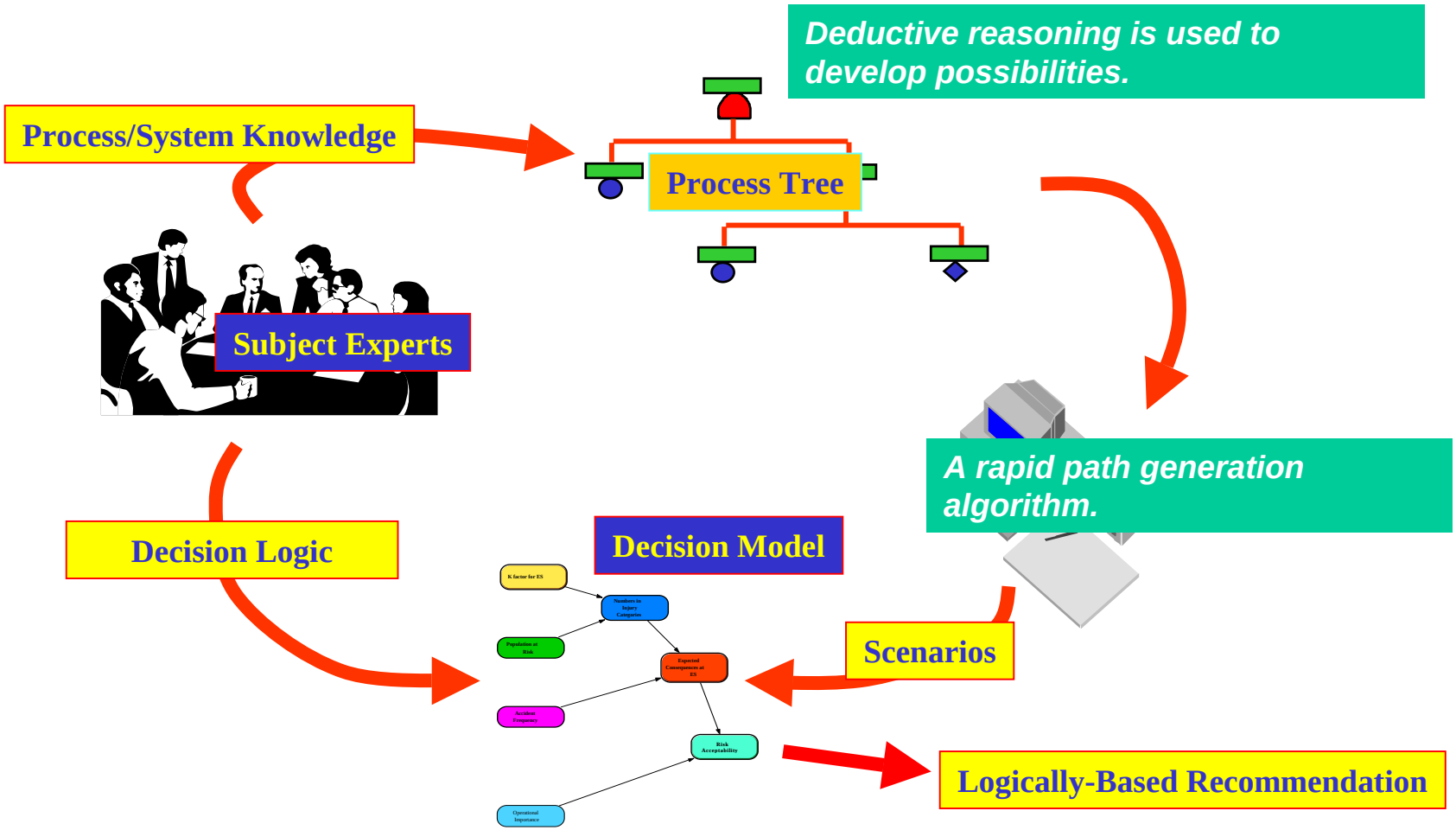
- *Ensure the HE replacement decision for a weapon has systematically considered all relevant factors, including survivability, reliability, maintainability, etc.*

Additional Objectives

- *Express the status and confidence of the cognizant experts for different possible replacement paths.*

- *Assign priorities to issue resolution based on the importance of the possible aging effect on weapon performance.*

We used an integrated approach to decision making in this problem that we call the Logic-Evolved Decision (LED) method.



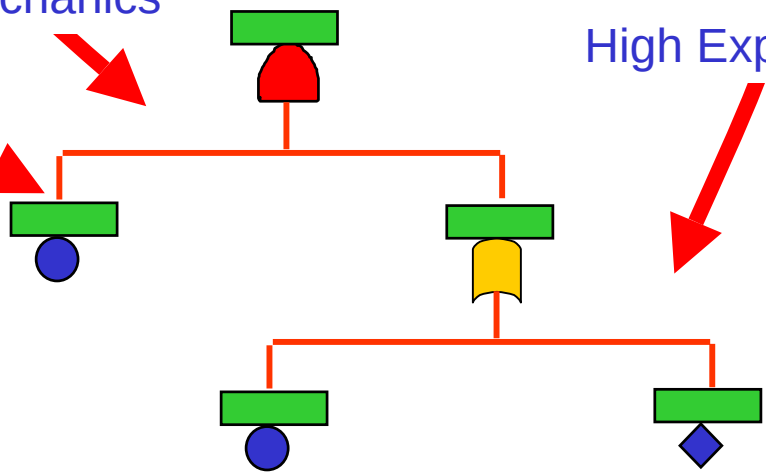
Process Tree Development for HE Replacement Decision Analysis

Chemistry

Solid Mechanics

High Explosives

Weapon Design



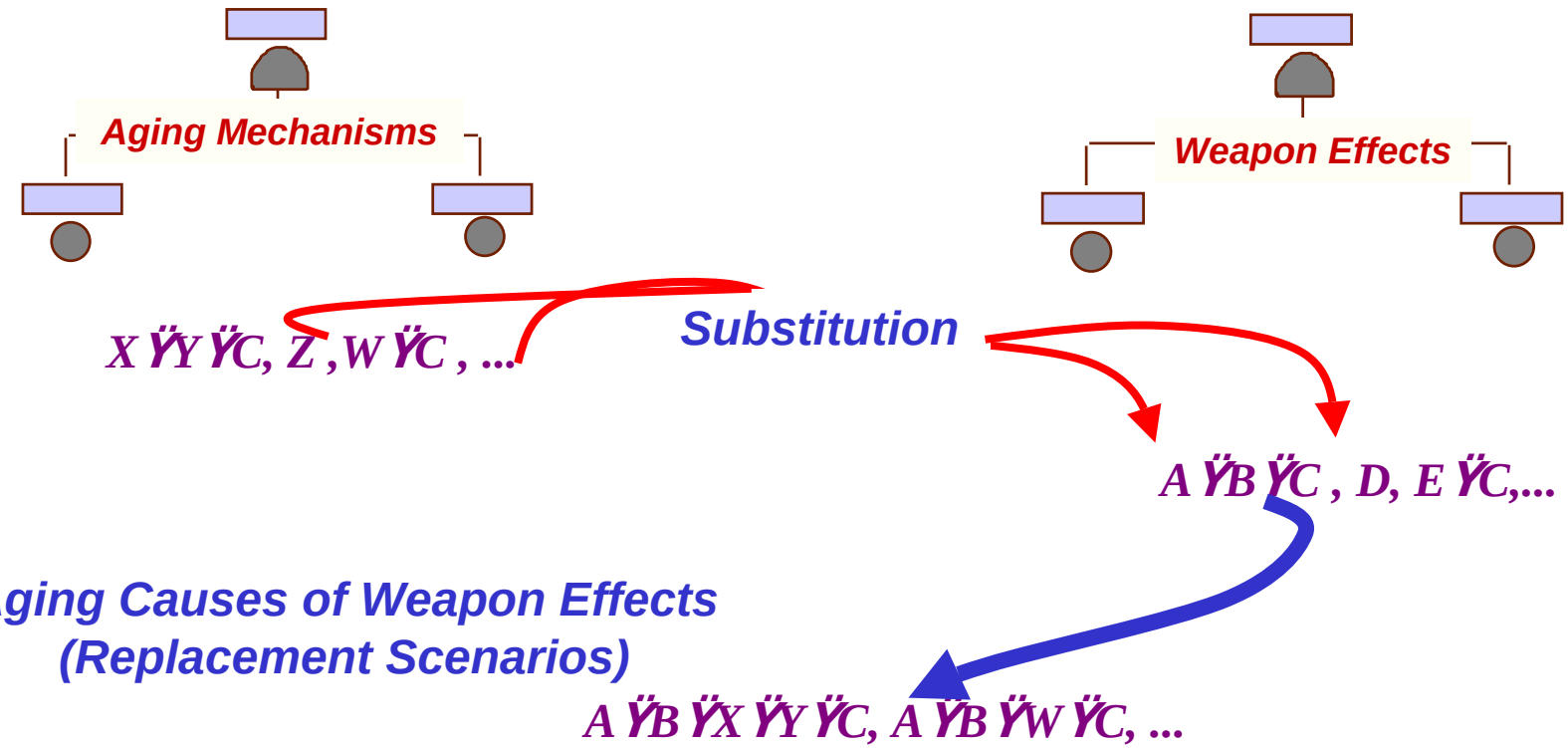
The tree enumerates possible paths that would necessitate HE replacement.

For practical reasons we developed two linked process trees:

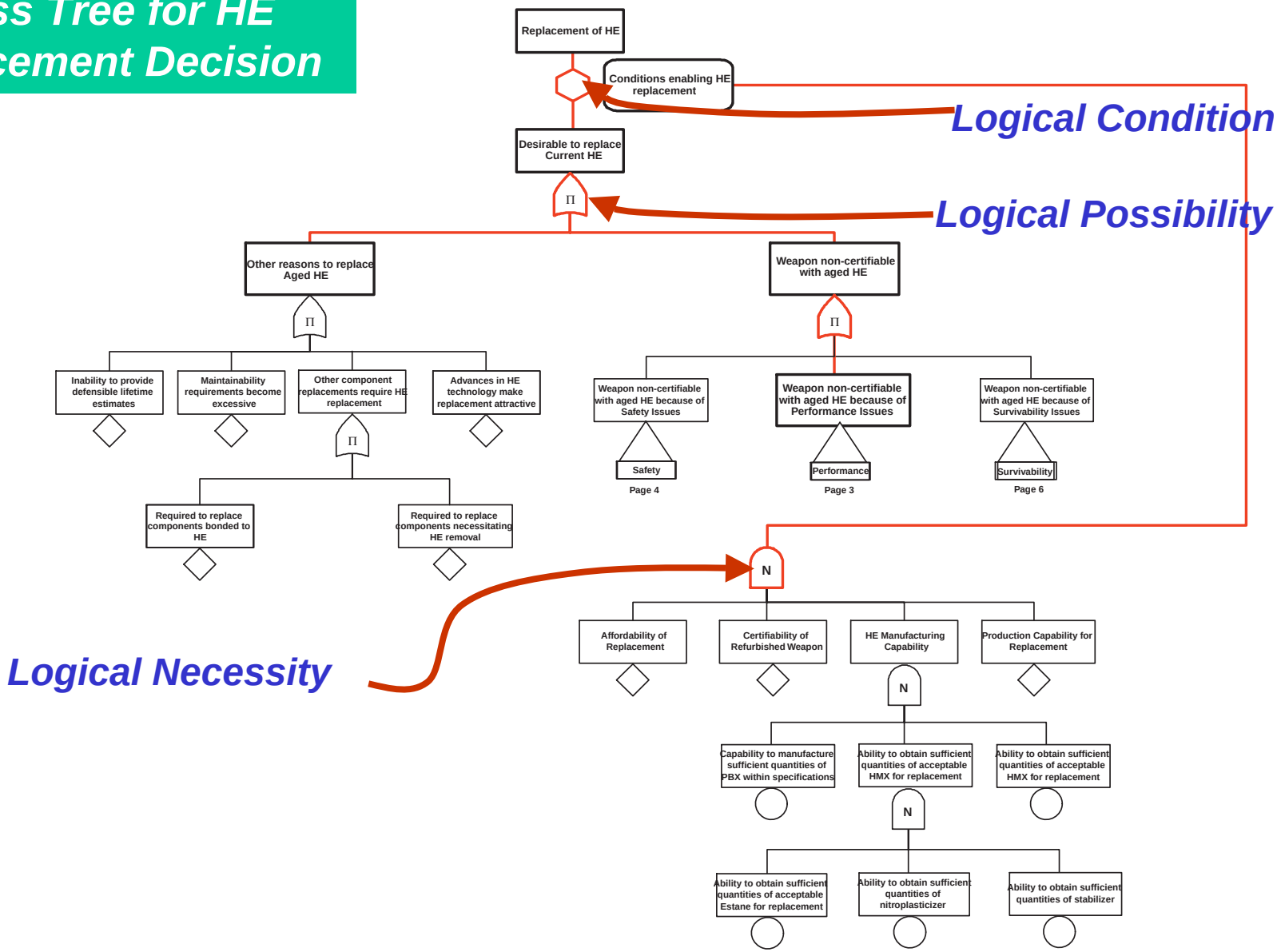
1) HE aging mechanisms and

2) Weapon effects arising from HE aging.

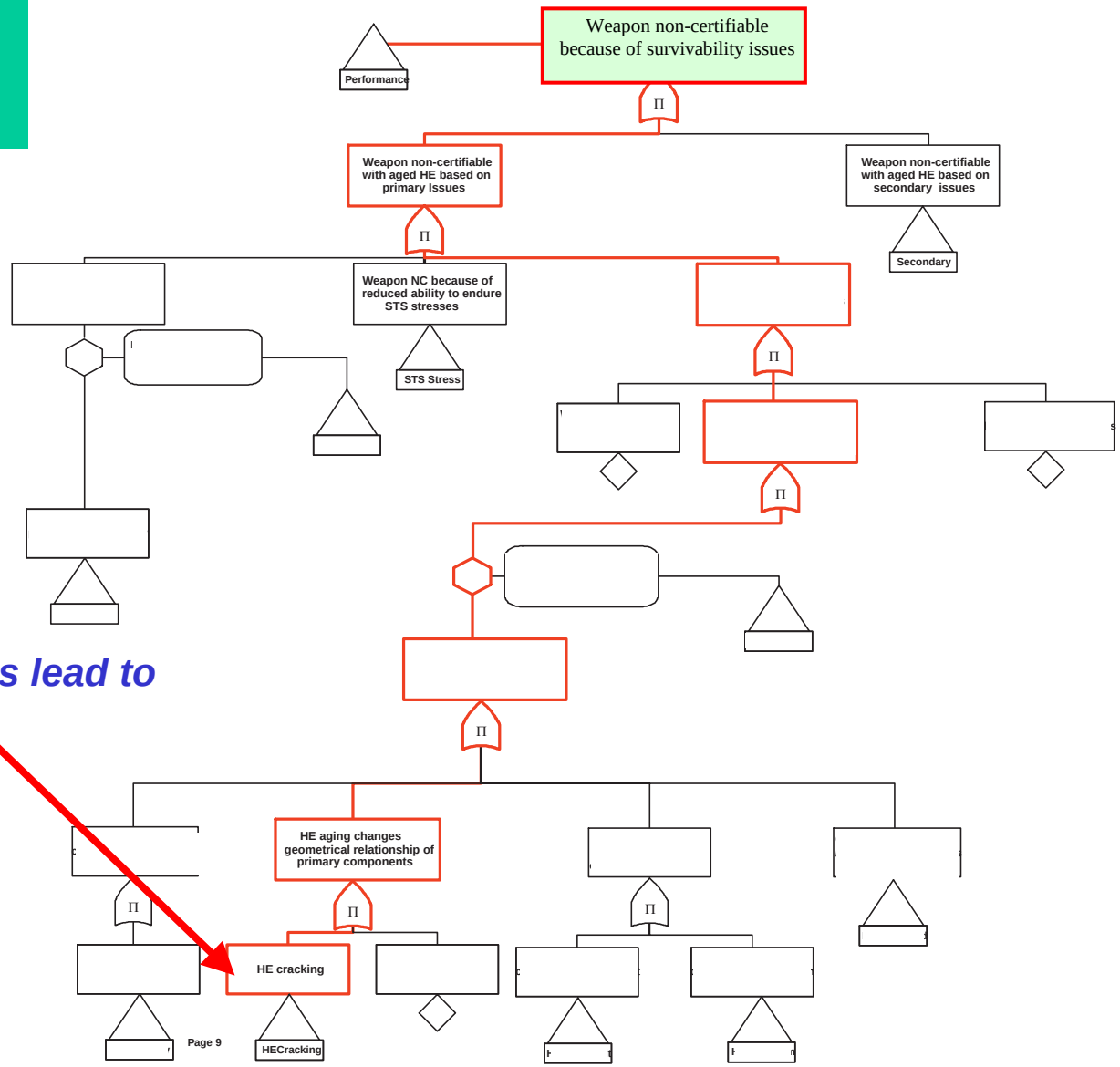
We then combined the the logic models.



Process Tree for HE Replacement Decision

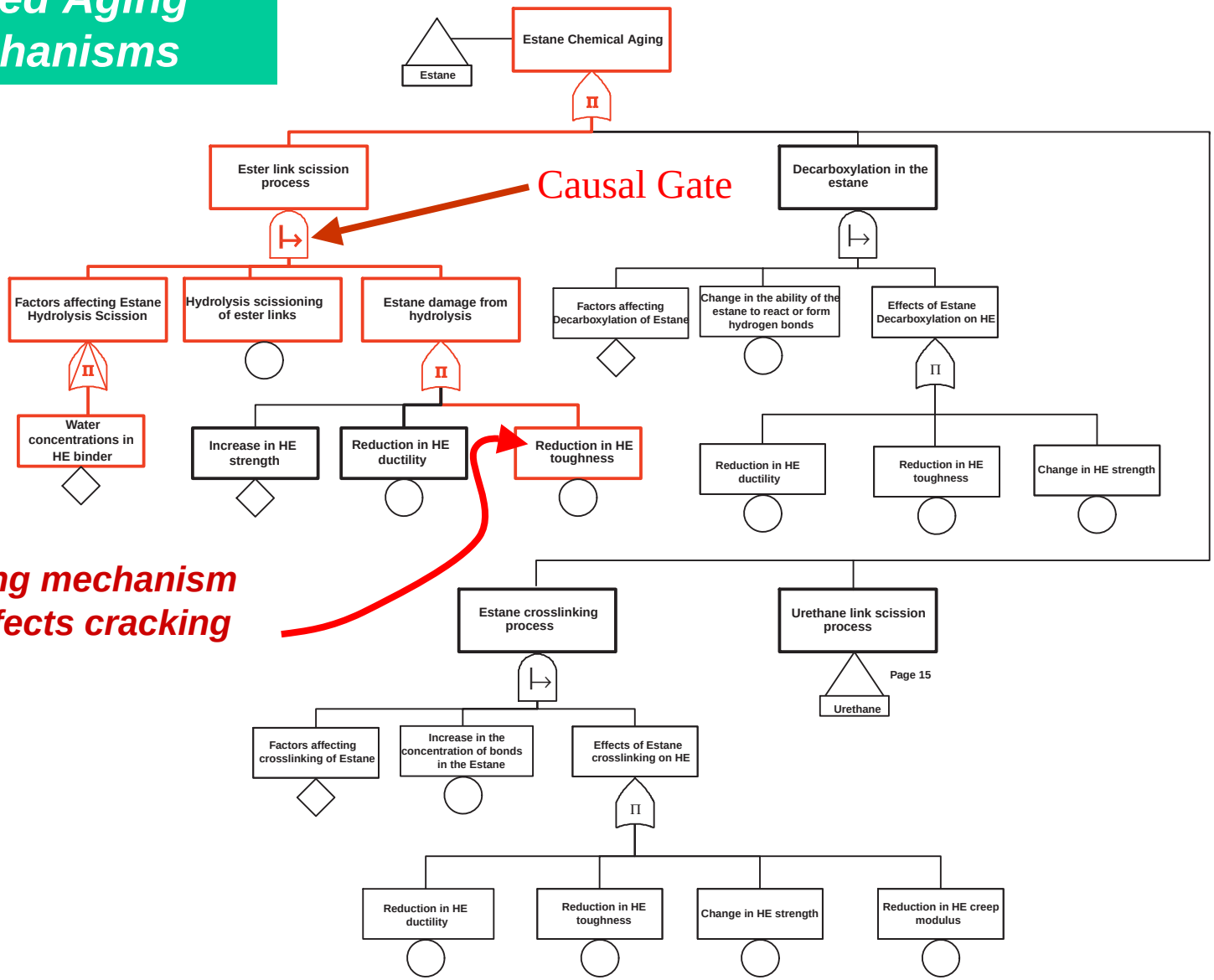


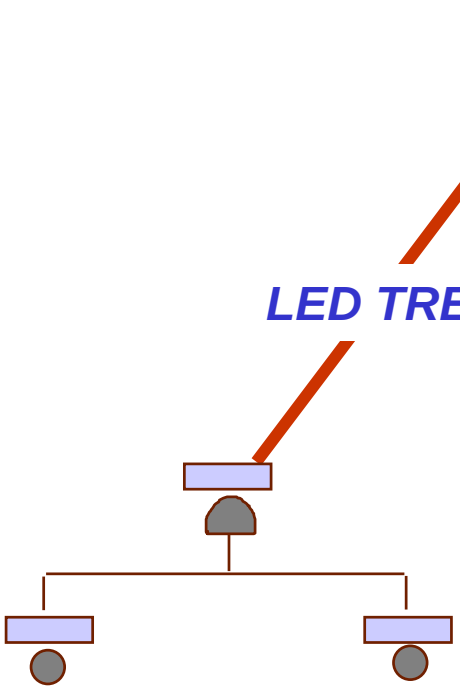
Branch for Performance-related Aging Effects



What aging mechanisms lead to HE cracking?

Branch for Estane-related Aging Mechanisms





Process Trees

LED TREE

Logical Equation

A ŸB ÆC ÆD

LED Path

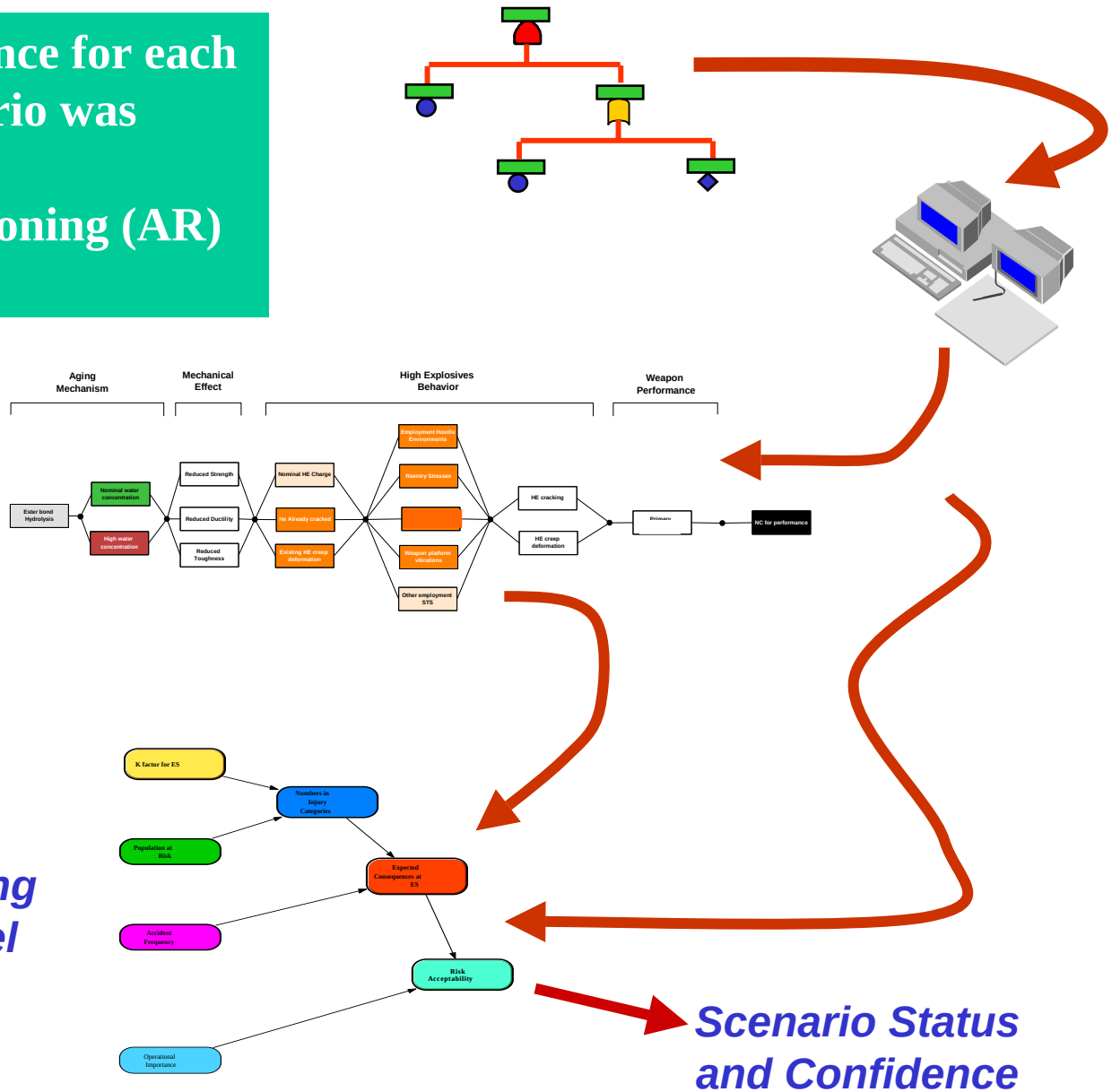
Path-Sets

A ŸB ŸC ,D ,B ŸE , ...

Each path-set is a possible sequence or set of conditions and events requiring HE replacement (a scenario).

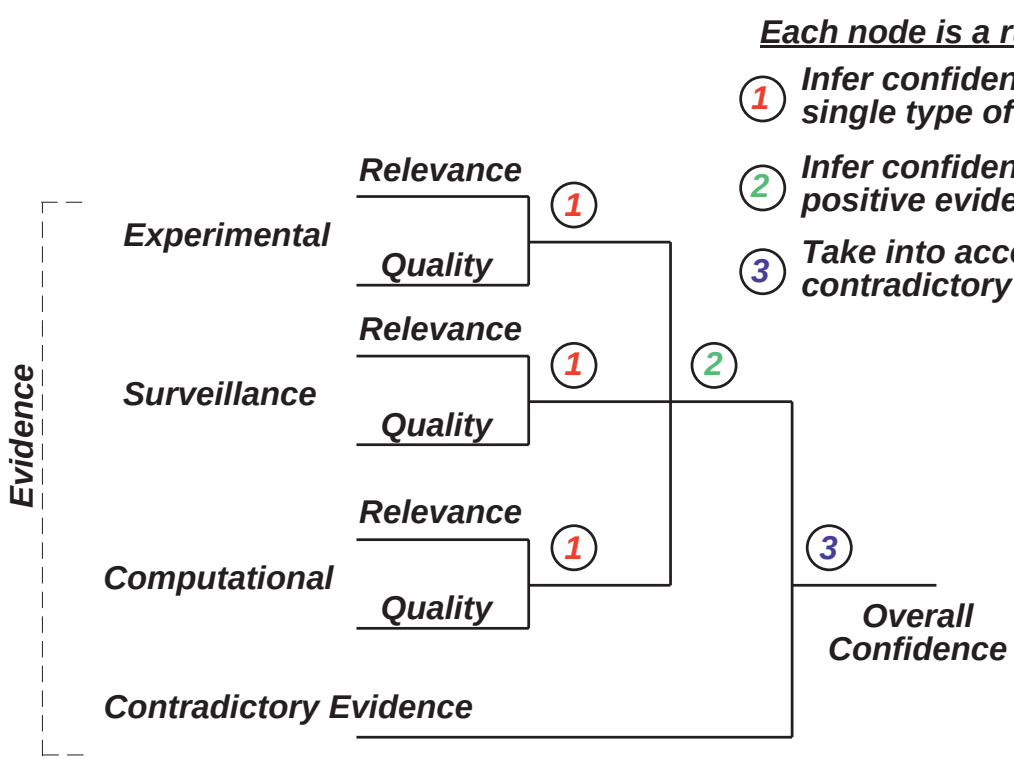
The process trees produce a logical model of the process that can be manipulated mathematically.

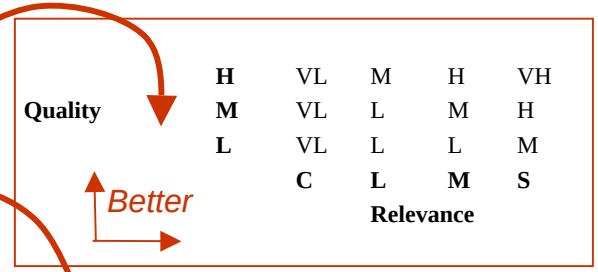
Status and confidence for each replacement scenario was evaluated using an Approximate Reasoning (AR) inference model.

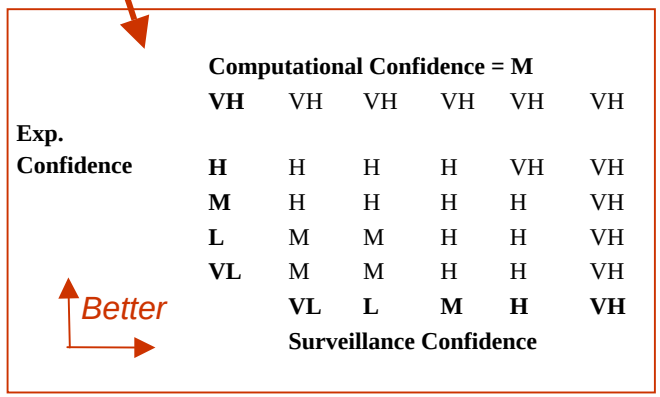


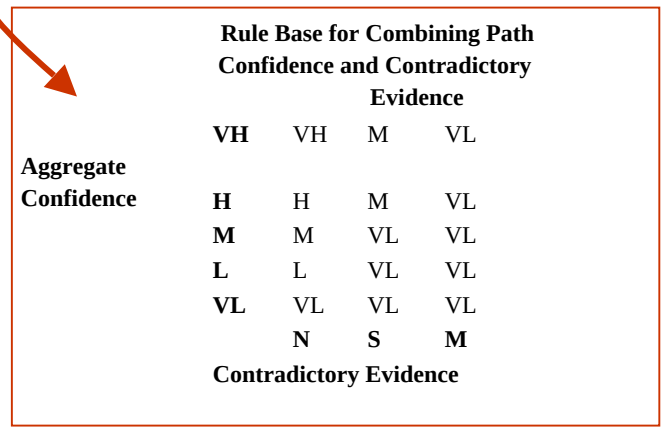
Forward Chaining Inference Model

Scenario Status and Confidence









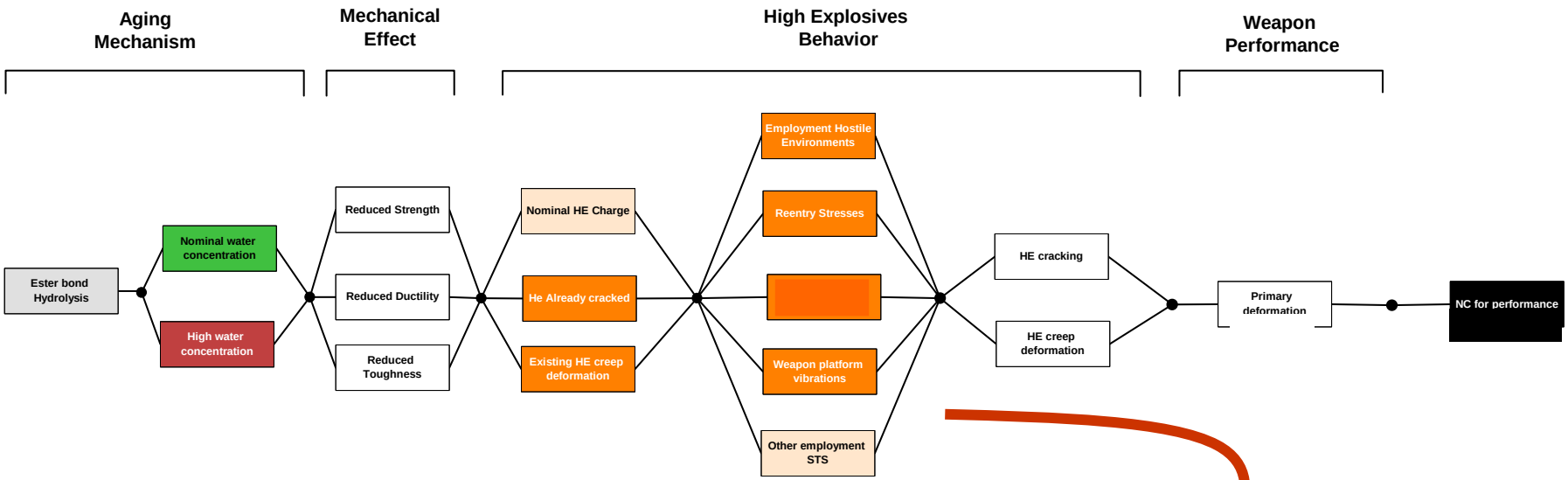
We carry out the chain of inference for each scenario to assess the confidence we have in its acceptability.

Status of Scenario

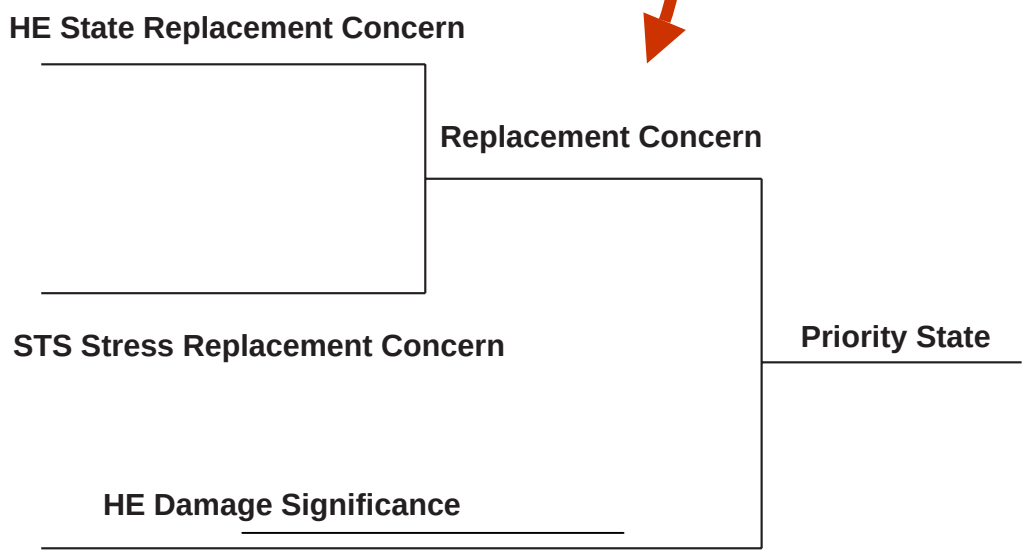
Confidence in status assessment

Scenarios developed from process tree

Initiating Event	Issue	Requirement	Function or State	Aging Effect	Process or Component	Path	Status	Confidence
					HE Initiability	1	Acceptable	High
					Detonators	2	Acceptable	Very High
					Boosters	3	Acceptable	Low
					Cables	4	Unresolved	
					Other	5	Unresolved	
	Performance	Reliability of function	Primary			6	Acceptable	Low
			Secondary			7	Acceptable	High
			STS			8	Unresolved	
		Pu Dispersal Risk	STS Environments		Thermal HEDD	9	Acceptable	Low
					Mechanical HEDD	10	Acceptable	Low
					Electrical HEDD	11	Acceptable	High
			Accident Conditions			12	Unresolved	
	Safety				Electrical IND	13	Acceptable	High
		IND Frequency	STS Environments		Thermal IND	14	Unresolved	
					Mechanical IND	15	Unresolved	
			Accident Conditions			16	Unresolved	
	Survivability	Probability of Survival	Hostile Conditions		Hostile Initiation	17	Acceptable	High
					Hostile Degradation	18	Unresolved	

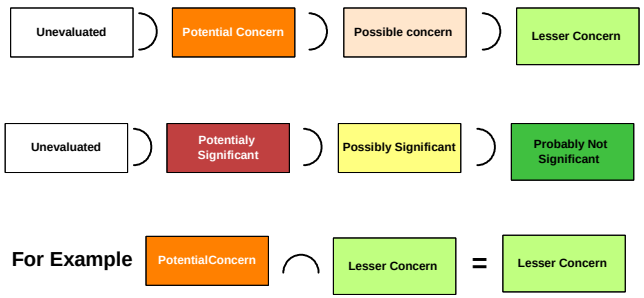


How Important are individual replacement scenarios?



The importance for a scenario is inferred through an AR model that uses the damage significance and replacement concern

Precedence Rules



Priority Evaluation Rule Base

Damage Mode Significance Evaluation

Replacement Mode Concern Evaluation

	Probably Not Significant	Possibly Significant	Potentially Significant
Lesser Concern	Lowest Priority	Low Priority	Medium Priority
Possible Concern	Low Priority	Medium Priority	High Priority
Potential Concern	Medium Priority	High Priority	Highest Priority

Graph Node Key

Decreasing Precedence in Determining Priority

Replacement Mode Concern

- Lesser Concern — This replacement mode is of **Lesser Concern**.
- Possible concern — This replacement mode is of **Possible Concern**.
- Potential Concern — This replacement mode is of **Potential Concern.**

Damage Mode Significance

- Probably Not Significant — This damage mode is **Probably Not Significant**.
- Possibly Significant — This damage mode is **Possibly Significant**.
- Potentialy Significant — This damage mode is **Potentially Significant**.

Special Graph Nodes

- Source Nodes
- Sink Nodes

Unevaluated — Not Evaluated

Evaluating the Importance for a scenario.

Concern Range 2

STS Stress Range

	Hostile	Reentry	Platform Vibrations	Other
Lesser	0	0	0	0.2
Possible	0.3	0.1	0.7	0.8
Potential	0.7	0.9	0.3	0

A linguistic variable

Concern Range 1

HE Initial State Range

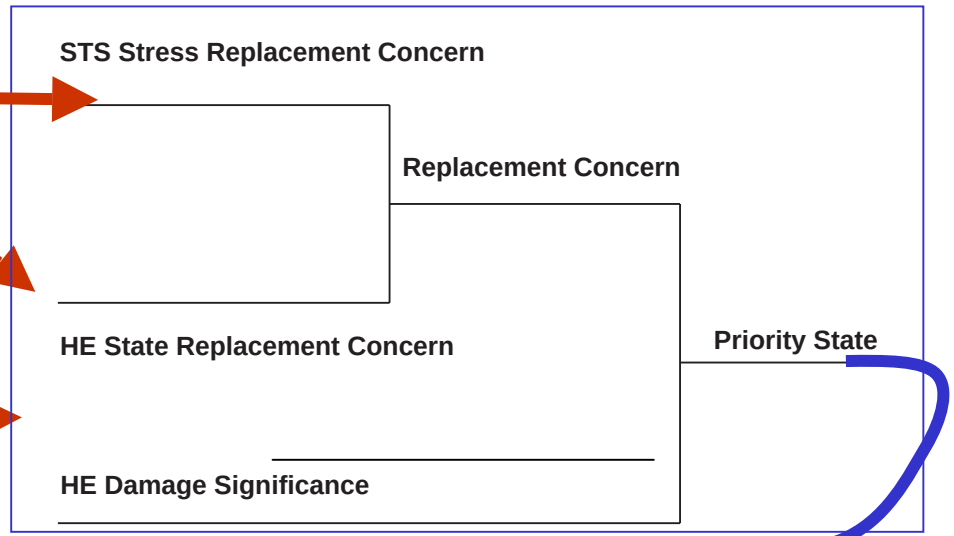
	Nominal HE	Cracked HE	Creeped HE
Lesser	0	0	0
Possible	1	0.1	0
Potential	0	0.9	1

A linguistic value for the variable

Damage Mode Range

Water Concentration Modes

	Nominal Water	High Water
Probably Not	1	0
Possibly	0	0.2
Potentially	0	0.8



Priority Range

STS Stress Range

	Hostile	Reentry	Platform Vibrations	Other
Lowest	0	0	0	0
Low	0	0	0	0.2
Medium	0.2	0.1	0.2	0.2
High	0.3	0.2	0.7	0.8
Highest	0.7	0.8	0.3	0

Conclusions

Comprehensive logical models of very complex processes can be constructed.

The logic models can be used to efficiently organize and manipulate the large amounts of information needed for decision making.

Complex concepts such as survivability and reliability can be addressed systematically and rigorously utilizing only qualitative knowledge.